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INVESTIGATION OF THE INFLUENCE OF EXTERNAL CONDITIONS ON THE STABILITY OF THE LASER RADIATION

Abstract. The article covers such issues as the refraction effect on the laser ray stability in the process of the reinforced concrete pipeline installation, when pipelines are heated by sunlight effect. Experimental analyses and results processing with changes in two-way analysis were conducted. To reduce the refraction influence and improve the accuracy of location survey it was proposed to use the method of geodesic measurements, which taking into account the construction work specifics.

Keywords: meteorological atmosphere parameters, optical air density, refraction, laser ray, two-way analysis of variance.

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ИССЛЕДОВАНИЕ ВЛИЯНИЯ ВНЕШНИХ УСЛОВИЙ НА СТАБИЛЬНОСТЬ ЛАЗЕРНОГО ИЗЛУЧЕНИЯ

Аннотация. В статье рассмотрены вопросы влияния рефракции на стабильность пучка лазерного излучения при устройстве железобетонных трубопроводов, нагретых под воздействием солнечных лучей. Выполнены экспериментальные исследования и обработка их результатов с изменением двух факторного анализа. Для уменьшения влияния рефракции и повышения точности разбивочных работ предлагается методика выполнения геодезических измерений, учитывающая специфику строительно- монтажных работ.

Ключевые слова: метеорологические параметры атмосферы, оптическая плотность воздушной среды, рефракция, лазерное излучение, двухфакторный дисперсионный анализ.

Due to changes in solar radiation, seasons of the year, time of day, meteorological atmospheric parameters — temperature, pressure, humidity, and their gradients, thermal characteristics of the Earth and its subsoil, soil cover of the Earth and so on. It changes the optical density of air, which leads to the known physical phenomena — refraction (bending of the trajectory of the light beam).

The angle between the tangent to the light beam in the starting and ending points of its trajectory straight line, connecting these points is called the angle of refraction. We differentiate between the angle of refraction, located in the horizontal plane.

As in the construction of sewage networks more strict requirements apply to snip altitude laying of pipelines, the focus in studies paid to refraction angle in the vertical plane.

At the present time, is widely and thoroughly studied issues related to the influence of refraction on the accuracy of individual types of geodetic measurements [2].

Detailed image of refraction studies in the Earth's atmosphere is made by I. G. Kolchinskiy in work [1].

It should be noted that work on the study of the earth's refraction in the vertical plane are related to geometric leveling, measuring the length of the optical range finders and geodetic leveling on large and small distances [1].

Of greatest interest are the results of studies [1], since the procedure of works geodetic leveling at short distances similar to the method of application of the laser beam in the construction of pipelines. Studies have shown [3], the main source of error geodetic leveling (vertical refraction), measurements must begin no earlier than three hours after sunrise and end no later than three hours before sunset.

Since the construction work for laying pipelines in the summer run mainly from 8 to 17 hours, then these time constraints are quite acceptable for the construction of sewerage networks.

All marked above studies were conducted in relation to the visual method of measurement and does not take into account peculiarities of the influence of the surface layer of the atmosphere on spreading in it laser beam of the research. It is known, however, that the effect of the environment in this case has its own specifics, due to a high degree of coherence, orientation, density and polarization of thr laser beam.

The specificity of action of the atmosphere on the laser beam is insufficiently considered in geodetic literature. Available information about the impact on the accuracy of vertical refraction "laser" methods of measurement are scarce, contradictory and often are only qualitative in nature. For example, in work [3] author is comparing curves refraction coefficient of variability for the "white" light and the laser beam, and comes to the conclusion that the laser radiation is more subject to refraction in passing through the atmosphere compared with conventional scattered light. In the same paper, the author makes reference that the value of the coefficient of refraction depends on the wavelength of the radiation source. And the author [4] proves the falsity of these views.

By determining the effect of the atmosphere on the propagation laws in its laser beam, researchers tend to share the phenomena into several groups, each of which is considered independently and take into account the specific use of lasers.

In the study of the influence of the environment on the accuracy of geodetic measurements, all phenomena are due to the action of the atmosphere are divided into two groups.

The first group includes events not associated with turbulence:

– reduces the intensity of the LIA (attenuation) as a result of the absorption of gas components and aerosol particles;
– attenuation due to scattering by density fluctuations and scattering aerosol particles;
– formation of background illumination;
– the curvature of the trajectory (refraction).

The second group includes phenomena caused by the turbulent nature of the atmospheric boundary layer:

– random variations in intensity;
– the loss of coherence of the polarization state;
– random changes pattern (random variations in the transverse dimensions of IPT);
– random changes the direction of propagation.

Above mentioned phenomenon is usually taken into account when selecting the energy parameters of the emitters and photodetectors, and thus their impact on the accuracy of measurements in large degree weakened.

Extensive research in Germany refractive laser [3]. In these studies described the methodologies to perform research in order to identify refractive distortion measurement accuracy using laser surveying instruments. Based on these results conclusions are drawn about the nature and magnitude of the effect of refraction on the stability of the laser beam in the atmospheric surface layer. For example, in work [4] drawn results on a vertical plane. Deviation of the laser beam from the middle position with the state of 100 m over eight hours of instrument was 4 arc minutes.

All of these studies were conducted at different geographical, climatic and meteorological conditions, different instruments, etc., thus take into account the diversity of an experiment in the specific application of laser surveying instruments.

When using a laser beam as a reference line in the production of geodetic work is the most important time of the beam. One of the causes of instability of the laser beam.

In this regard, we have made special studies in Kazakhstan (where the summer temperature usually reaches 40 °C and above), whose purpose was to determine the degree of influence of the length of the laser beam refraction and the accuracy of geodetic measurements at high ambient temperatures.

For these purposes, the construction site was secured basis length 100 m with intermediate points through 10 m, which is fixed by metal pins. The laser device is installed at the starting point and took readings on rail level on the remaining points of the basis in the horizontal position of the laser beam. The observations were made during the day with an interval of 1 hour with simultaneous measurement of air temperature. The temperature was varied from 17 °C (in the morning and evening) to +35 °C (at noon).

To determine the degree of impact of changes in the distance and ambient temperature on the stability of the laser beam (the null hypothesis) we used two-factor analysis of variance.

To analyze the results of studies using the following formula:

$$Q_1 = \sum_{i=1}^{v} \frac{\left(\sum_{j=1}^{v} x_{ij}\right)}{v} - \frac{\left(\sum_{i=1}^{\tau}\sum_{j=1}^{v} x_{ij}\right)}{\tau v},$$

$$Q_2 = \sum_{j=1}^{v} \frac{\left(\sum_{i=1}^{v} x_{ij}\right)}{\tau} - \frac{\left(\sum_{i=1}^{\tau}\sum_{j=1}^{v} x_{ij}\right)}{\tau v},$$

$$Q_3 = \sum_{i=1}^{\tau}\sum_{j=1}^{v} x^2{}_{ij} \frac{\sum_{i=1}^{\tau} x_{ij}\left(\sum_{j=1}^{v} x_{ij}\right)}{v} - $$

$$- \frac{\sum_{j=1}^{v}\left(\sum_{i=1}^{\tau} x_{ij}\right)}{\tau} + \frac{\left(\sum_{i=1}^{\tau}\sum_{j=1}^{v} x_{ij}\right)}{\tau v},$$

$$Q = \frac{\sum_{i=1}^{\tau}\sum_{j=1}^{v} x^2{}_{ij} - \left(\sum_{i=1}^{\tau}\sum_{i=1}^{v} x_{ij}\right)}{\tau v}$$

where τ, v — the number of observations on the grounds.

Middle rows and columns of Table, calculated criteria

$$F_A = \frac{\frac{1}{r-1} Q_1}{\frac{1}{(r-1)(u-1)} Q_3} = \frac{S_1^2}{S_3^2}$$

$$F_B = \frac{\frac{1}{u-1}Q_2}{\frac{1}{(r-1)(u-1)}Q_3} = \frac{S_2^2}{S_3^2}$$

(r — 1), (u — 1) — degree of freedom.

Using the relations (3.22) — (3.25) we have

$$Q_1 = \frac{90{,}88}{13} - \frac{8{,}8^2}{9\cdot 13} = 6{,}99 - 0{,}66 = 6{,}33\ \text{mm}^2$$

$$Q_2 = \frac{185{,}36}{9} - 0{,}66 =$$
$$= 20{,}59 - 0{,}66 = 19{,}93\ \text{mm}^2$$

Q_3 = 594,23 — 20,59 — 6,99 + 0,66 = 567,31 mm^2

Q_4 = 594,23 — 0,66 = 593,57 mm^2

Results of analysis of variance are given in Table.

$$F_b = \frac{5{,}59}{0{,}79} = 7{,}47\ ,$$

And for the mean square (between the temperature range):

$$F_T = \frac{5{,}90}{1{,}66} = 3{,}55\ .$$

According to Table we find that for the first case the practical border is F_5 = 2.99 and F_1 = 4.98, and for the second case F_5 = 2.36 and F_1 = 3.47.

The value of F_b and F_t fall in the critical region, so the null hypothesis is refuted, i.e. the length of the laser beam and the temperature have a significant effect on its stability.

Earlier, we noted that a number of special tripods and other accessories designed for the installation of devices in the vicinity of the surface structures, the position of which is controlled during the installation. Therefore it is very important to know the boundaries, remove the laser beam from the surface of building structures, in which will be the smallest loss of accuracy due to the effect of refraction.

The results of analyzes of variance

Variance components	Sum of squares	The number of degrees of freedom	Mean square
Between the points of the basis	6,33	8	0,79
Between the temperature range	19,93	12	1,66
Residual	567,31	96	5,90
Total (full)	593,57	116	5,12

According to this table, the null hypothesis test is made using F-test: for the mean square “between points basis”:

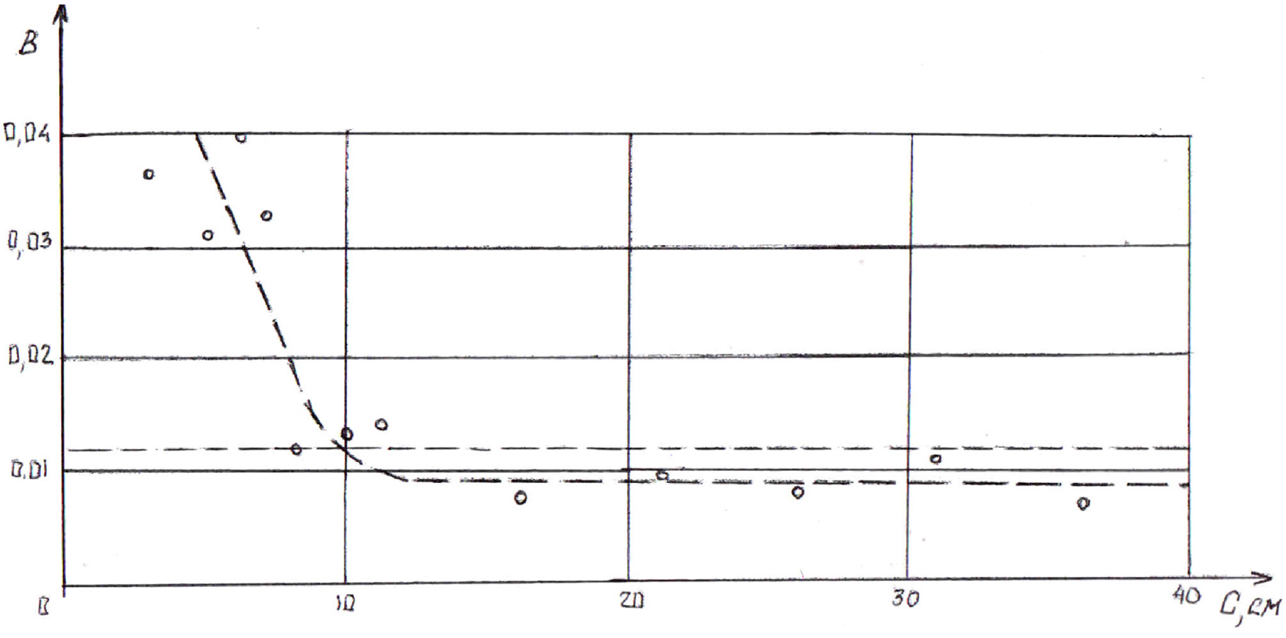

Fig. 1. Dependence of the parameter B on the height (C) of the laser beam over the pipe

To investigate this question were carried out experimental measurements on the laser beam unit five intermediate points on the 12-parallel cross-sections remote from the surface of the pipe at a distance of 3 cm (first target) to 36 cm (twelfth target). The distance between points 15 m. When the air temperature on the surface of the pipe from 26 °C to 30 °C for each cross-section was performed leveling points and eight lots of different observers.

Based on the results of these studies it was made graphic of dependency on stability of the laser beam on the distance from the surface of the heated concrete pipe solar rays (Fig. 1).

Analyzing the results of the studies we conclude that the effect of the heated pipe is less noticeable when the laser beam is located at a distance above on sm on the surface of the concrete pipe.

References

1. Kolchinskii I. G. *Refraktsiia sveta v zemnoi atmosphere* [Refraction of light in the Earth's atmosphere]. Kiev, Naukova dumka Publ., 1967. 44 p. (In Russ.).

2. Kushtin I. F. *Refraktsiia svetovykh luchei v atmosphere* [Refraction light rays in atmosphere]. Moscow, Nedra Publ., 1971. 68 p. (In Russ.).

3. Malkovsky O. About effect of vertical refraction to spread rays gas lasers. *Izvestia vyzov "Geodesy and aerophotography"*, 1983. no. 4, pp. 51–54.

4. Yambayev Kh. K. Precision molecular weight measurement. Moscow, Nedra Publ., 1978. 225 p. (In Russ.).

5. Smirnov N. V., Belugin D. A. *Teoriia veroiatnostei i matematicheskaia statistika v prilozhenii k geodezii* [Theory Probability and mathematical statistics in application to geodesy]. Moscow, Nedra Publ., 1969. 389 p. (In Russ.).